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DO GRADES OF COTTON REFLECT CELLULOSE DETERIORATION?

A Study of the 1937 Crop 1/

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The American cotton crop is sold principally on the basis of official U. S. Standards for grade and for staple length. Length of cotton fibers is a varietal characteristic subject to modification by growing and ginning conditions. Grade, on the other hand, is much less influenced by variety. Grade is predicated on the logical assumption that cotton which is bright and normal in color, picked clean, and ginned well, is worth more than cotton that is dirty or abnormal in color, full of leaf and trash, and poorly ginned. As issued by the U. S. Department of Agriculture under the U. S. Cotton Standards Act, the Universal Standards for Grades of American upland cotton are accepted and used all over the world by those who trade in American upland cotton. Those now in force (1942) are listed in table 1. They are discussed in detail in other publications of the U. S. Department of Agriculture (7, 8, 9). 3/

As a whole, the grades have rather definite significance in mill practice in terms of relative cost of raw materials, yield and quality of products, and costs of processing and finishing. However, even at the present time there is little scientific information as to how cotton fiber quality varies with the grade of the raw cotton. Willis (10) reported in 1927 on manufacturing tests of cotton of the White grades of the Universal Standards for American cotton in force at that time. Among other things, he reported that the strength of the yarn did not always follow the grade of the cotton, but that there was a tendency for the higher grades to produce stronger yarns. Nickerson 4/ studied the

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1/ The work herein reported was conducted in the laboratories of the Agricultural Marketing Administration at Washington, D. C., in cooperation with the Bureau of Plant Industry, and is a part of the joint program of cotton fiber research conducted by the Agricultural Marketing Administration and the Bureau of Plant Industry.

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3/ Figures in parentheses refer to Literature Cited, p. 15.

4/ Nickerson, Dorothy. Grade of Cotton Affected by Exposure in the Field. U.S. Dept. Agr., Bur. Agr. Econ. 12 pp., illus. 1933. (Processed.)
------ Studies of Color in Raw Cotton. Prelim. Rpt. U. S. Dept. Agr., Bur. Agr. Econ. 22 pp., illus. 1933. (Processed.)

Table 1. - Official standards for grades of American upland cotton 1/

Gray (G)	Extra White (EW)	White	Spotted (Sp.)	Tinged (T)	Yellow Stained (YS)
		No. 1, or Middling Fair (MF)			
		No. 2, or Strict Good Middling (SGM)			
GM G	GM EW	No. 3, or Good Middling (GM)	GM Sp.	GM T	GM YS
SM G	SM EW	No. 4, or Strict Middling (SM)	SM Sp.	SM T	SM YS
M G	M EW	No. 5, or Middling (M)	M Sp.	M T	M YS
	SLM EW	No. 6, or Strict Low Middling (SLM)	SLM Sp.	SLM T	
	LM EW	No. 7, or Low Middling (LM)	LM Sp.	LM T	
	SGO EW	No. 8, or Strict Good Ordinary (SGO)			
	GO EW	No. 9, or Good Ordinary (GO)			

1/ Underlined symbols denote grades for which practical forms or grade boxes of the standards are prepared for public distribution. The grades indicated by symbols not underlined are descriptive grades and are not represented by grade boxes. Middling Fair White cotton is that which in color, leaf, and preparation is better than Strict Good Middling. Gray cotton is that which is more gray in color than that in the boxes for White cotton; Spotted cotton is that which in color is between the White and the Tinged; Yellow Stained is that which is more yellow in color than the Tinged; and Extra White is that which is whiter in color than the White grades. The grades shown above the horizontal lines are deliverable on futures contracts made in accordance with section 5 of the United States Cotton Futures Act. Those below these lines are not deliverable on such contracts.

influence upon the color and grade of the resulting lint of continued field exposure of the seed cotton in the boll on the plant. She observed in most cases a rather rapid lowering of the color factors as well as of the grade as exposure was continued. She suggested that color might be an index of other quality changes, although the results of strength measurements were rather inconclusive. Similar results were reported by Grimes (4) who noted in addition to the color and grade changes a fairly general loss of strength of the raw cotton. The results thus suggested that deterioration of the cellulose might occur, and that its degree might vary with the grade of the cotton.

By far the largest and most important constituent of the lint of cotton is the cellulose. Of the dry weight of the fiber, it constitutes from perhaps 80 to about 95 percent, the proportion depending largely on the degree of fiber wall development. Its importance to the finished textile product is shown by the fact that most of the kiering and bleaching operations in cotton manufacture are designed to get rid of all other constituents.

The opportunities for cellulose deterioration from the opening of the cotton boll until the beginning of manufacture are numerous. Exposure of the seed cotton in the field to sunlight containing appreciable portions of the ultraviolet radiation is suggested, on the basis of work by Grimes (3), as one source of such deterioration. Even more serious for the cellulose, however, may be the action of fungi and other microorganisms, which, with sufficient moisture from dew or rain, and with suitable temperature, may grow upon the fiber, secreting enzymes which rapidly destroy the cellulose. The action of frost in releasing active enzymes in unopened bolls may be still another source of cellulose deterioration. The action of weather and the nutrient condition of the soil during growth may be still other pertinent factors affecting the quality of the cellulose laid down in the fiber. Finally, conditions of storage which permit excessive moisture in the seed cotton or ginned lint or which give rise to heating, may easily cause serious deterioration of the cellulose.

No record has been found of chemical tests made to determine the quality of the cellulose in relation to the different grades of cotton, although many studies have dealt with cellulose deterioration under various conditions. The purpose of the present study was to survey in a preliminary way the percentages of cellulose in the available grades of cotton from the 1937 crop and to measure the quality of the cellulose by appropriate means. Such a study was made relatively simple since cotton samples are collected each year for the purpose of making a survey of the variations of lint color in the crop. Samples for 1937 were the first to be available for chemical tests, and the present report is concerned only with the 1937 samples. Samples for 1939 and 1940, however, have since been collected and are being held for the same purpose.

Materials and Methods 5/

In 1937 more than 4,700 samples from the aforementioned color survey, collected from four of the field offices of the Cotton Division of the Agricultural Marketing Service, (now a part of the Agricultural Marketing Administration) were made available for study. The samples were believed to be representative of all American upland cottons in the 1937 crop except those from the irrigated districts of the far West. Samples for this survey were received each week from each field office. These offices, located at Atlanta, Ga.; Memphis, Tenn.; Dallas, Tex.; and Austin, Tex., in turn obtained the samples from selected gins throughout their territories. The samples received in

5/ Appreciation is expressed to members of the Agricultural Marketing Administration, as follows: The staff of the regional offices, who supplied the original samples for the color survey; Dorothy Nickerson, who composited the samples according to grade and made them available for the present study; the staff of the Spinning Laboratory at Clemson, S. C., for cleaning the samples; and Meyer D. Silverman for assistance with the chemical analyses.

Washington consisted of one bag of samples selected at random each week from the work of each regular classer stationed at each of the four offices. After the samples were measured for color in the laboratory and were classed by the Appeal Board, a small portion of each was put aside for the present study in containers identified to show the region of origin and the grade assigned by the Appeal Board. The number of original samples composited and their distribution by originating office, color class, and grade number, are shown in table 2. In some instances the composited samples from one grade were combined with an equal quantity of the composited samples of another grade in order to provide sufficient material for analysis. Although other grades besides those listed in this table were found, the number of samples or the quantity of cotton was too small to permit chemical analysis.

All the samples contained some trash; the lower grades had a very high content of nonfibrous material. Some of the smaller samples were carefully cleaned by hand. However, since such cleaning proved to be very time-consuming, most of the samples were cleaned with the aid of a Shirley analyzer. In two instances the samples proved exceedingly difficult to clean; and they were passed through the analyzer three or four times before the foreign matter could be completely removed.

Both during cleaning due to the mechanical action and again by hand before removing the portion required for chemical analysis, the lint was thoroughly mixed. A 10-gram sample was taken and cut in a Wiley mill until it passed through a 1-millimeter sieve. The entire sample was then placed in a thimble in a large (50 by 250 mm.) Soxhlet extractor and extracted for successive 4-hour periods with water and 95 percent ethyl alcohol to remove residual sugars, waxes, and other interfering substances. Between water and alcohol extractions and again after the alcohol extraction, the cotton was allowed to dry thoroughly in a current of air. It was then passed through the Wiley mill a second time to break up conglomerated masses. Finally, it was stored in 4-ounce screw cap bottles until used.

Samples for the different analyses were, for the most part, weighed out consecutively. The cellulose analysis, however, was not undertaken until after the other analyses had been completed. Besides the cellulose content, the moisture content, and the alkali solubility, the copper number and the cuprammonium fluidity of the cellulose were determined on each sample. The cellulose determination, besides showing the degree of cell-wall development, also furnished a basis for adjusting the measures of cellulose deterioration.

The moisture content was used only in computing cellulose content of the samples. It was determined by drying 0.25-gram samples in triplicate to constant weight in an air oven at from 104° to 110° C.

Cellulose was determined in duplicate on 0.1-gram samples according to a method described elsewhere by the authors. 6/ The sample was boiled for 2 hours under a reflux condenser with 1,000 volumes of 1 percent sodium hydroxide,

6/ Kettering, J. H. and Conrad, Carl M. Determination of Cellulose in Raw Cotton. (Accepted for publication in Ind. Eng. Chem., Anal. Ed.)

Table 2. - Number of original samples composited and their distribution by region, grade number, and color class

Region and grade number (Symbol)	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	All classes
	Number	Number	Number	Number	Number	Number
Atlanta:						
3 (GM)	-	42	16	-	-	58
4 (SM)	-	208	151	-	-	359
5 (M)	-	460	336	-	1	797
6 (SLM)	-	455	128	-	-	583
7 (LM)	-	146	13	-	-	159
8 (SGO)	-	2	-	-	-	2
9 (GO)	-	2	-	-	-	2
Total	-	1315	644	-	1	1960
Memphis:						
3 (GM)	-	8	3	-	-	11
4 (SM)	-	218	76	5	-	299
5 (M)	1	322	120	18	-	461
6 (SLM)	-	137	52	15	-	204
7 (LM)	-	37	11	2	-	50
8 (SGO)	-	14	9 1/	25 1/	-	48
9 (GO)	-	4	-	11 1/	-	15
Total	1	740	271	76	-	1088
Dallas:						
3 (GM)	-	-	3	-	-	3
4 (SM)	-	114	55	-	-	169
5 (M)	-	200	97	7	-	304
6 (SLM)	-	91	109	14	-	214
7 (LM)	-	40	60	9	-	109
8 (SGO)	-	23	13 1/	-	-	36
9 (GO)	-	-	-	-	-	-
Total	-	468	337	30	-	835
Austin:						
3 (GM)	-	34	11	-	-	45
4 (SM)	-	203	113	-	-	316
5 (M)	-	182	49	-	-	231
6 (SLM)	-	82	47	5	-	134
7 (LM)	-	15	27	5	-	47
8 (SGO)	-	-	16 1/	61 1/	-	77
9 (GO)	-	-	7 1/	13 1/	-	20
Total	-	516	270	84	-	870
Grand total	1	3039	1522	190	1	4753

1/ No official standards for these grades; see table 1.

filtered and washed with the aid of suction. The purified residue was oxidized with standard acid dichromate, and the unused dichromate was titrated with ferrous ammonium sulfate. O-phenanthroline ferrous complex was used as an internal indicator for the titration. The dichromate consumed in the oxidation was computed to cellulose by means of the factor, 0.00675 gram cellulose per milliliter of normal dichromate.

Alkali solubility was determined in triplicate on 0.1-gram samples by a slight modification of the micro-method described by Nodder (6). The soda boil was omitted since it, admittedly, dissolves part of the short-chain cellulose which it was desired to include in the determination. After triturating the sample for 15 minutes at 25° C. with one milliliter of 10 N sodium hydroxide, the mixture was diluted to 2.0 N and allowed to stand for 1 hour, during which time it was frequently stirred. An aliquot portion of the clear filtered extract from the sample was then oxidized with acid potassium dichromate, and the residual dichromate was determined with ferrous ammonium sulfate, through the use of o-phenanthroline-ferrous-complex as internal indicator. The volume of reduced dichromate in milliliters of normal solution was computed to grams of cellulose by means of the factor, 0.00675.

The copper number was determined in triplicate on 0.25-gram samples of the cotton, according to a modification of the Heyes (5) micro-method. The sample was covered with 10 ml. of the hot copper-carbonate-bicarbonate reagent in a special 3/4-inch test tube, was provided with a ground glass air condenser and was heated for exactly 3 hours in a glycerine bath, maintained at 100° C. The tubes were shaken occasionally during heating. The mixture of cotton and Cu_2O was then collected on an asbestos mat in a Gooch crucible and washed. The Cu_2O was dissolved with 3 ml. of acid ferric sulfate solution, added in two portions. The filtrate and washings, amounting to about 30 ml., were caught in a 50 ml. Erlenmeyer flask and titrated with 0.01 normal potassium permanganate. O-phenanthroline-ferrous-complex indicator was used to increase the sensitivity of the end point. A blank determination was run, and the permanganate was standardized against weighed quantities of CU_2O prepared from known sugar solutions. Results were computed on the basis of the cellulose in the sample.

The fluidity in cuprammonium solution was determined in duplicate on samples of the cotton at a concentration of 0.5 gram cellulose per 100 ml. solution according to a method described by Conrad (2). Briefly, the method consists in measuring with a double-action stop watch the successive time intervals required for 5 ml. portions of the cuprammonium-cellulose solution to flow through calibrated capillaries at successively decreasing head. The cuprammonium solution contained 30 grams of copper, 165 grams of ammonia, and 10 grams of sucrose per liter, as specified by the Committee on Viscosity of Cellulose of the American Chemical Society (1). The capillaries were 2.50 ± 0.01 cm. long and had a radius of from 0.0702 to 0.0737 cm. as determined by mercury calibration. The mean head, $\underline{h}$, during flow was computed with the aid of Meissner's formula

$$h = \frac{h_1 - h_2}{\log_e (h_1/h_2)}$$

in which $\underline{h_1}$ and $\underline{h_2}$ are the height in centimeters above the capillary at the upper and lower rings for any flow interval. Kinetic energy corrections were taken from

a previously constructed chart, based on the evaluation of the quantity

$$\frac{m d V}{8 \pi L t}$$

in which m is the kinetic energy coefficient, taken as 1.12; d is the density of the solution, determined to be 0.974, V is the volume of flow, i.e., 5 ml.; L is the length of the capillary; and t is the time required for 5 ml. to discharge. The fluidity values were adjusted also for variations of cellulose concentration with the aid of a fluidity-concentration table and interpolated to a mean velocity gradient of 500 sec.$^{-1}$. with the aid of log-log coordinate paper. The formula used to compute the mean velocity gradient, G, was

$$G = \frac{8 V}{3 \pi R^3 t}$$

in which V and t have the same significance as in the kinetic energy quantity given above and R is the radius of the capillary in centimeters.

Results

The results of the analyses are shown in figures 1 to 5 and in tables 3 to 7. Figure 1 shows the average cellulose content and the average alkali solubility, copper number, and cuprammonium fluidity of the cellulose for each of the composite grades for the four regions combined; and figures 2 to 5 show this information separately for the Atlanta, Memphis, Dallas and Austin regions.

By reference to figure 1 it will be seen that the cellulose content was, on the average, rather uniform for the different grades of cotton. The two poorer grades of White cotton (the lower being one of the compounded grades, however, and from the Memphis area alone) contained a somewhat higher cellulose content than the mean whereas the corresponding grades of Spotted cotton showed an appreciably lower cellulose content. A lower cellulose content is associated with a lower fiber maturity, i.e., a lesser cell wall development. This lack of development may be due to arrest of growth by various weather and nutritional conditions, to attacks by microorganisms and insects, to killing frosts, or to any combination of them.

The alkali solubility, copper number, and cuprammonium fluidity all show a general trend upward as the grades become lower. The fluidity change is rather small for all color classes; but alkali solubility and copper number show very appreciable increases with decrease in grade in the Spotted and Tinged cotton. These increases are all indicative of more or less general deterioration of the cellulose as the grade becomes lower. Increase of copper number is indicative of oxidation of the cellulose with or without disruption of the long-chain molecules, or of hydrolytic cleavage. Increase in the alkali solubility and fluidity, however, is indicative of either an actual or potential molecular rupture with a shortening of the length of the chains.

It is of interest, however, to consider the grades by regions since it is conceivable that the results of figure 1 could be due to the averaging of rather divergent results from the different geographical regions. The relation

Table 3.- Cellulose content of composite samples

Region and grade number (Symbol)	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	Weighted average 1/
	Percent	Percent	Percent	Percent	Percent	Percent
Atlanta:						
3 (GM)	-	93.3	93.3	-	-	93.3
4 (SM)	-	93.6	92.2	-	-	92.9
5 (M)	-	93.8	94.4	-	92.2	93.5
6 (SLM)	-	94.1	93.6	-	-	93.8
7 (LM)	-	92.3	96.2	-	-	94.2
8 (SGO)	-	93.5	-	-	-	93.5
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	93.4	93.9	-	92.2	93.6
Memphis:						
3 (GM)	-	96.3	94.1	-	-	95.2
4 (SM)	-	93.2		92.9	-	93.4
5 (M)	91.0	92.3	94.4	95.2	-	93.2
6 (SLM)	-	94.4	95.5	94.8	-	94.9
7 (LM)	-	93.9	95.0		-	94.6
8 (SGO)	-	95.3	94.3 2/	93.7 2/	-	94.4
9 (GO)	-		-	93.5 2/	-	94.4
Weighted average 1/	91.0	94.4	94.6	94.2	-	94.2
Dallas:						
3 (GM)	-	-	92.8	-	-	92.8
4 (SM)	-	90.8	93.4	-	-	92.1
5 (M)	-	89.8	93.3	90.7	-	91.3
6 (SLM)	-	88.5	90.2	88.3	-	89.0
7 (LM)	-	84.8	90.4	90.4	-	88.5
8 (SGO)	-	92.3	92.1 2/	-	-	92.2
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	89.2	92.0	89.8	-	90.6
Austin:						
3 (GM)	-	89.7	91.8	-	-	90.8
4 (SM)	-	93.1	92.0	-	-	92.6
5 (M)	-	92.2	91.5	-	-	91.8
6 (SLM)	-	92.7	92.6	90.1	-	91.8
7 (LM)	-	92.5	91.3	90.3	-	91.4
8 (SGO)	-	-	88.8 2/	88.1 2/	-	88.4
9 (GO)	-	-	86.7 2/	88.8 2/	-	87.8
Weighted average 1/	-	92.0	90.7	89.3	-	90.8
Grand weighted average 1/	91.0	92.5	92.7	91.7	92.2	92.4

1/ Weighted on basis of composite grades represented.

2/ No official standards for these grades. See table 1.

Table 4. - Alkali solubility of the cellulose of composite samples

Region and grade number (Symbol)	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	Weighted average 1/
	Percent	Percent	Percent	Percent	Percent	Percent
Atlanta:						
3 (GM)	-	1.49	1.53	-	-	1.51
4 (SM)	-	1.15	2.10	-	-	1.62
5 (M)	-	1.28	1.65	-	2.10	1.68
6 (SLM)	-	1.33	1.76	-	-	1.54
7 (LM)	-	1.71	2.38	-	-	2.04
8 (SGO)	-	1.70	-	-	-	1.70
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	1.44	1.88	-	2.10	1.68
Memphis:						
3 (GM)	-	1.63	1.56	-	-	1.60
4 (SM)	-	1.54		2.09	-	1.73
5 (M)	1.58	1.90	1.60	1.85	-	1.73
6 (SLM)	-	1.52	.91	1.85	-	1.43
7 (LM)	-	1.87	1.21		-	1.64
8 (SGO)	-	2.00	1.30 2/	1.30 2/	-	1.53
9 (GO)	-		-	1.42 2/	-	1.71
Weighted average 1/	1.58	1.78	1.36	1.73	-	1.63
Dallas:						
3 (GM)	-	-	1.88	-	-	1.88
4 (SM)	-	1.89	1.92	-	-	1.90
5 (M)	-	2.07	2.28	3.67	-	2.67
6 (SLM)	-	2.08	2.90	3.96	-	2.98
7 (LM)	-	2.55	3.29	3.34	-	3.06
8 (SGO)	-	2.37	2.51 2/	-	-	2.44
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	2.19	2.46	3.66	-	2.62
Austin:						
3 (GM)	-	2.58	3.61	-	-	3.10
4 (SM)	-	2.30	2.75	-	-	2.52
5 (M)	-	2.78	3.19	-	-	2.98
6 (SLM)	-	2.64	2.50	3.36	-	2.83
7 (LM)	-	2.68	3.19	3.70	-	3.19
8 (SGO)	-	-	3.99 2/	4.64 2/	-	4.32
9 (GO)	-	-	4.94 2/	4.50 2/	-	4.72
Weighted average 1/	-	2.60	3.45	4.05	-	3.33
Grand weighted average 1/	1.58	1.96	2.35	2.89	2.10	2.30

1/ Weighted on basis of composite grades represented.

2/ No official standards for these grades. See table 1.

Table 5. - Copper number of the cellulose of composite samples

Region and grade number (Symbol)	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	Weighted average 1/
	Percent	Percent	Percent	Percent	Percent	Percent
Atlanta:						
3 (GM)	-	0.27	0.24	-	-	0.26
4 (SM)	-	.22	.29	-	-	.26
5 (M)	-	.24	.33	-	0.58	.38
6 (SLM)	-	.29	.33	-	-	.31
7 (LM)	-	.35	.38	-	-	.36
8 (SGO)	-	.32	-	-	-	.32
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	0.28	0.31	-	0.58	0.32
Memphis:						
3 (GM)	-	0.24	0.31	-	-	0.28
4 (SM)	-	.26		0.37	-	.31
5 (M)	0.33	.32	.32	.38	-	.34
6 (SLM)	-	.32	.28	.45	-	.35
7 (LM)	-	.40	.42		-	.42
8 (SGO)	-	.45	.46 2/	.40 2/	-	.44
9 (GO)	-		-	.49 2/	-	.47
Weighted average 1/	0.33	0.35	0.35	0.42	-	0.37
Dallas:						
3 (GM)	-	-	0.38	-	-	0.38
4 (SM)	-	0.41	.40	-	-	.40
5 (M)	-	.37	.44	1.25	-	.69
6 (SLM)	-	.36	.73	1.57	-	.89
7 (LM)	-	.51	.70	1.34	-	.85
8 (SGO)	-	.49	.58 2/	-	-	.54
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	0.43	0.54	1.39	-	0.68
Austin:						
3 (GM)	-	0.36	0.39	-	-	0.38
4 (SM)	-	.35	.41	-	-	.38
5 (M)	-	.34	.41	-	-	.38
6 (SLM)	-	.38	.50	1.02	-	.63
7 (LM)	-	.39	.71	1.21	-	.77
8 (SGO)	-	-	1.28 2/	1.89 2/	-	1.58
9 (GO)	-	-	1.72 2/	1.68 2/	-	1.68
Weighted average 1/	-	0.36	0.77	1.44	-	0.81
Grand weighted average 1/	0.33	0.35	0.51	0.96	0.58	0.54

1/ Weighted on basis of composite grades represented.

2/ No official standards for these grades. See table 1.

Table 6. - Cuprammonium fluidity of the cellulose of composite samples

Region and grade number (Symbol)	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	Weighted average 1/
	Rhes	Rhes	Rhes	Rhes	Rhes	Rhes
Atlanta:						
3 (GM)	-	2.08	2.04	-	-	2.06
4 (SM)	-	1.90	2.06	-	-	1.98
5 (M)	-	1.96	2.18	-	1.95	2.03
6 (SLM)	-	2.10	2.17	-	-	2.14
7 (LM)	-	2.17	2.42	-	-	2.30
8 (SGO)	-	2.20	-	-	-	2.20
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	2.07	2.17	-	1.95	2.10
Memphis:						
3 (GM)	-	1.98	1.98	-	-	1.98
4 (SM)	-	1.92		1.91	-	1.94
5 (M)	2.29	1.90	1.98	1.94	-	2.03
6 (SLM)	-	2.04	2.10	1.98	-	2.04
7 (LM)	-	2.36	2.21		-	2.18
8 (SGO)	-	2.38	2.08 2/	1.98 2/	-	2.15
9 (GO)	-		-	2.02 2/	-	2.20
Weighted average 1/	2.29	2.14	2.06	1.97	-	2.07
Dallas:						
3 (GM)	-	-	1.85	-	-	1.85
4 (SM)	-	1.86	1.97	-	-	1.92
5 (M)	-	1.78	2.04	2.36	-	2.06
6 (SLM)	-	1.83	2.05	2.19	-	2.02
7 (LM)	-	1.80	2.11	2.20	-	2.04
8 (SGO)	-	2.20	2.36 2/	-	-	2.28
9 (GO)	-	-	-	-	-	-
Weighted average 1/	-	1.89	2.06	2.25	-	2.04
Austin:						
3 (GM)	-	1.87	1.91	-	-	1.89
4 (SM)	-	1.92	1.98	-	-	1.95
5 (M)	-	1.95	1.99	-	-	1.97
6 (SLM)	-	2.16	2.10	2.28	-	2.18
7 (LM)	-	2.08	2.39	2.48	-	2.32
8 (SGO)	-	-	2.28 2/	2.58 2/	-	2.43
9 (GO)	-	-	2.38 2/	2.45 2/	-	2.42
Weighted average 1/	-	2.00	2.15	2.45	-	2.18
Grand weighted average 1/	2.29	2.04	2.11	2.18	1.95	2.10

1/ Weighted on basis of composite grades represented

2/ No official standards for these grades. See table 1.

Table 7. - Summary of data by grade color, determination, and region

Determination and region	Color class					
	Gray	White	Spotted	Tinged	Yellow Stained	Weighted average
	Percent	Percent	Percent	Percent	Percent	Percent
Cellulose:						
Atlanta	-	93.4	93.9	-	92.0	93.5
Memphis	91.0	94.4	94.6	94.2	-	94.2
Dallas	-	89.2	92.0	89.8	-	90.6
Austin	-	92.0	90.7	89.3	-	90.8
Weighted average	91.0	92.5	92.7	91.7	92.0	92.4
Alkali sol:						
Atlanta	-	1.44	1.88	-	2.10	1.68
Memphis	1.58	1.78	1.36	1.73	-	1.63
Dallas	-	2.19	2.46	3.66	-	2.62
Austin	-	2.60	3.45	4.05	-	3.34
Weighted average	1.58	1.96	2.35	2.89	2.10	2.30
Copper No.:						
Atlanta	-	0.28	0.31	-	0.58	0.32
Memphis	0.33	.35	.35	0.42	-	.37
Dallas	-	.43	.54	1.39	-	.68
Austin	-	.36	.77	1.44	-	.81
Weighted average	0.33	0.35	0.51	0.96	0.58	0.54
Fluidity:	Rhes	Rhes	Rhes	Rhes	Rhes	Rhes
Atlanta	-	2.07	2.17	-	1.95	2.10
Memphis	2.29	2.14	2.06	1.97	-	2.07
Dallas	-	1.89	2.06	2.25	-	2.04
Austin	-	2.00	2.15	2.45	-	2.17
Weighted average	2.29	2.04	2.11	2.18	1.95	2.10

of cellulose content and quality to grade for the Atlanta region are shown in figure 2. By reference to this figure it will be seen that the cellulose content is very uniform for the different grades. No. 7, Spotted, presents a slight exception in that the cellulose content of this grade, representing a composite of 13 original samples, is somewhat high and indicates rather unusually well matured fibers. The alkali solubility, the copper number, and the cuprammonium fluidity values, although trending generally upward with decreasing grade, are rather moderate in their changes - much more so, in fact, than their averages in the Spotted and Tinged grades of figure 1. The values for grade No. 5, Stained, are from a single original sample and may not therefore, adequately represent this grade.

The results for the Memphis region are shown in figure 3. The picture is very similar to that for the Atlanta region except that the alkali solubility shows something of a downward trend in the Spotted and Tinged grades. The Tinged grades from this region are well represented.

The results for the Dallas region are shown in figure 4. Here the cellulose contents are in general quite noticeably lower than those for the two preceding regions, which fact indicates that the fibers were less completely matured. Although there are exceptions, there is some tendency (see also table 3) for the cellulose content to become lower with lower grades, thus indicating greater immaturity of fiber in the lower grades. In the White and Spotted cottons the measures of cellulose deterioration also show increasing deterioration as the grade becomes lower.

In Spotted grades 6 and 7, and in all the Tinged grades, the alkali solubility and the copper number were especially high. There is a tendency for the average value of each of the measures of cellulose deterioration to increase with increasing grade color. Thus, the Dallas samples show a much greater average deterioration as the grade becomes lower than do the Atlanta or the Memphis samples. The cause for this is not immediately evident.

Figure 5 shows the results for the Austin region. The cellulose content of the White grades is about like that for the Atlanta and Memphis regions, except for No. 3, which is rather low. In the Spotted and Tinged grades, the cellulose content tends to become lower as the grade becomes lower, in the same way as was observed for the Dallas samples. In the White grades, the alkali solubility and the copper number are quite similar to the corresponding values from other regions. In the Spotted and Tinged grades, however, these values rise as the grade becomes lower, until they even exceed the changes observed for the Dallas region, thus indicating unmistakable deterioration. All cellulose deterioration values increase with increasing color of the cotton.

Discussion of Results

The results, as a whole, show a rather uniform cellulose content so far as grade is concerned with the exception of some of the lower grades from the Austin area. However, the cellulose content of the cottons from the two eastern regions averaged distinctly higher than that of the cottons from the western regions, thus indicating for the 1937 crop year a rather greater cellulose deposition in the former, i.e., a higher degree of maturity. The low cellulose content in the Spotted and Tinged grades from the Austin area probably indicates interruption of the natural development of the fiber by frost.

Interpretatively, the alkali solubility may be taken as a measure of the amount of short chain fragments of cellulose which have resulted from the deterioration produced by one or more agencies. An increased copper number may be taken as a measure of oxidative or hydrolytic deterioration, with or without the rupture of the long chain cellulose molecules. However, when increased copper number values are accompanied by increased values of alkali solubility and cuprammonium fluidity, it also suggests the splitting of long chain cellulose molecules with resulting increase in number of short chain molecules. Although the copper number is perhaps the most sensitive of the three measures of deterioration, it is also the most unreliable one in its exact interpretation, since in oxidative degradation it often increases to a maximum and then decreases on further action. The cuprammonium fluidity, however, may be considered as a functional measure of mean cellulose chain length.

The alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the different composite samples all indicated a gradually increasing deterioration that was fairly consistent as the grades became lower. At the same time, there was a general trend toward greater deterioration with increasing grade color. Alkali solubility and copper number indicated that the deterioration of the cellulose was of a greater degree in the Texas regions than in the eastern areas, but the fluidity of the cellulose did not show any appreciable distinction. The appearance of greatly higher copper numbers in the Texas areas, where the amount and intensity of the sunlight would be expected to be greater, might suggest actinic deterioration. However, the possible influence of microorganisms as well as of frost in causing the greater deterioration in those regions cannot be eliminated without additional and more extensive studies. Whether such differences are accidental or are of yearly occurrence remains to be determined by additional work.

Summary and Conclusions

For the crop year of 1937, composite grade samples from all cotton-growing regions except those in the far western part of the United States were examined for cellulose content and comparative deterioration of the cellulose. The regions into which the Cotton Belt was divided for the purpose of this study are those centering around Atlanta, Ga.; Memphis, Tenn.; Dallas, Tex.; and Austin, Tex. The number of samples which were composited for each grade is shown; it varied from 1 to 460.

The percentage of cellulose in the fiber was found to show relatively little variation with grade except in the Spots and Tinges of the Austin area. The cellulose content of cottons from the two eastern regions, however, was noticeably higher, as a whole, than that of the cottons from the two Texas areas.

Three measures of cellulose deterioration were applied, and all indicated a trend toward greater deterioration as the grade number became lower or as the grade color increased. Based on copper number and alkali solubility, the Texas cottons showed much greater degrees of deterioration as the grade became lower than did the cottons from the two eastern regions. Cuprammonium fluidity did not show this difference. Greater exposure in those regions

to actinic rays is suggested as a possible explanation of the greater degrees of deterioration, although microorganisms and the action of frost may not be overlooked.

More work is needed to show how general is the relation between grade of cotton and cellulose deterioration found in the present study, and whether it is sufficient to be of economic or commercial importance. If deterioration, in greater or less degree, is prevalent, as seems probable on the basis of the present work, then it will be desirable to learn how it is related to varieties of cotton, regions of growth, and seasonal conditions.

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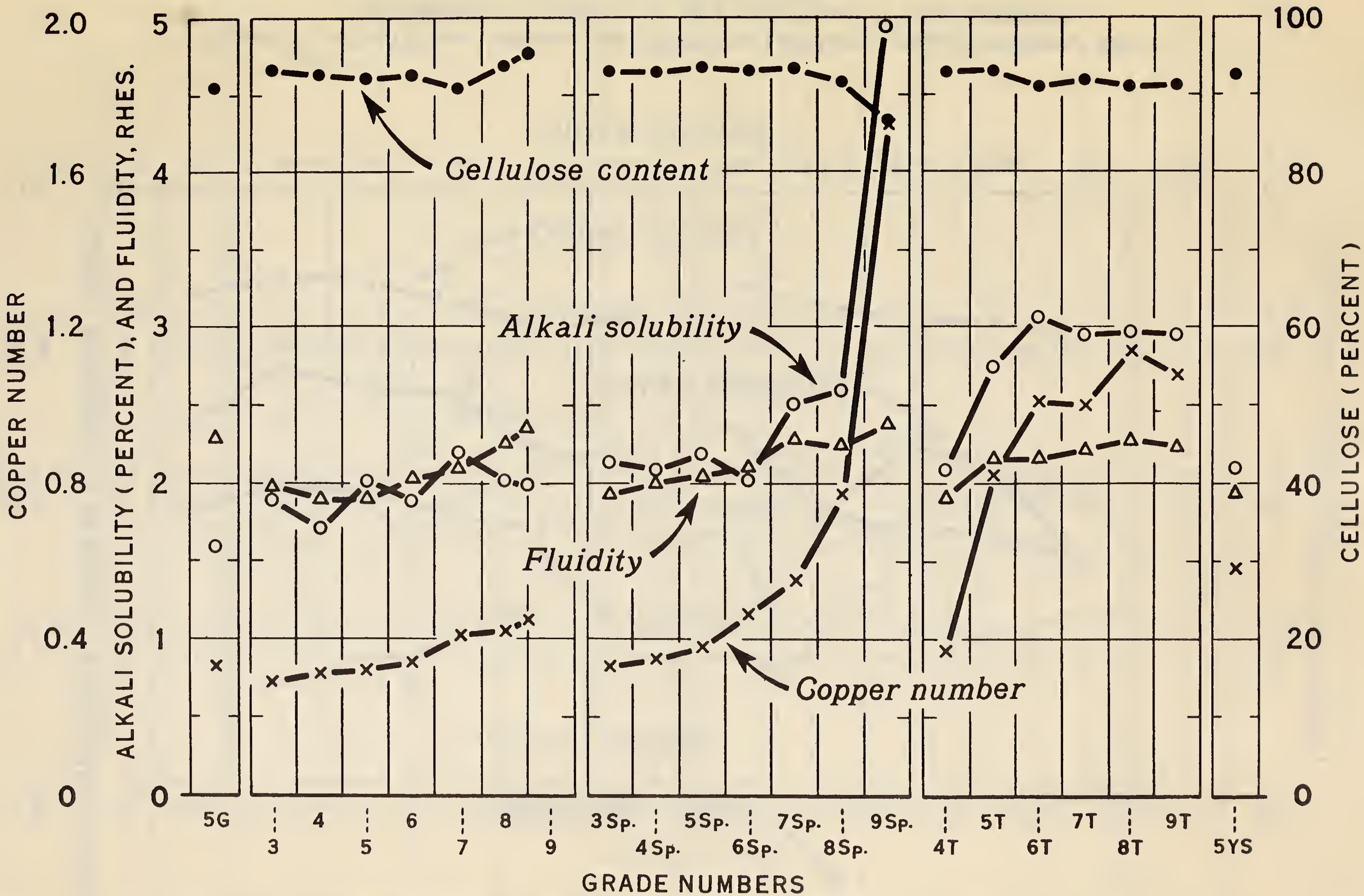

Figure 1.--Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from all regions

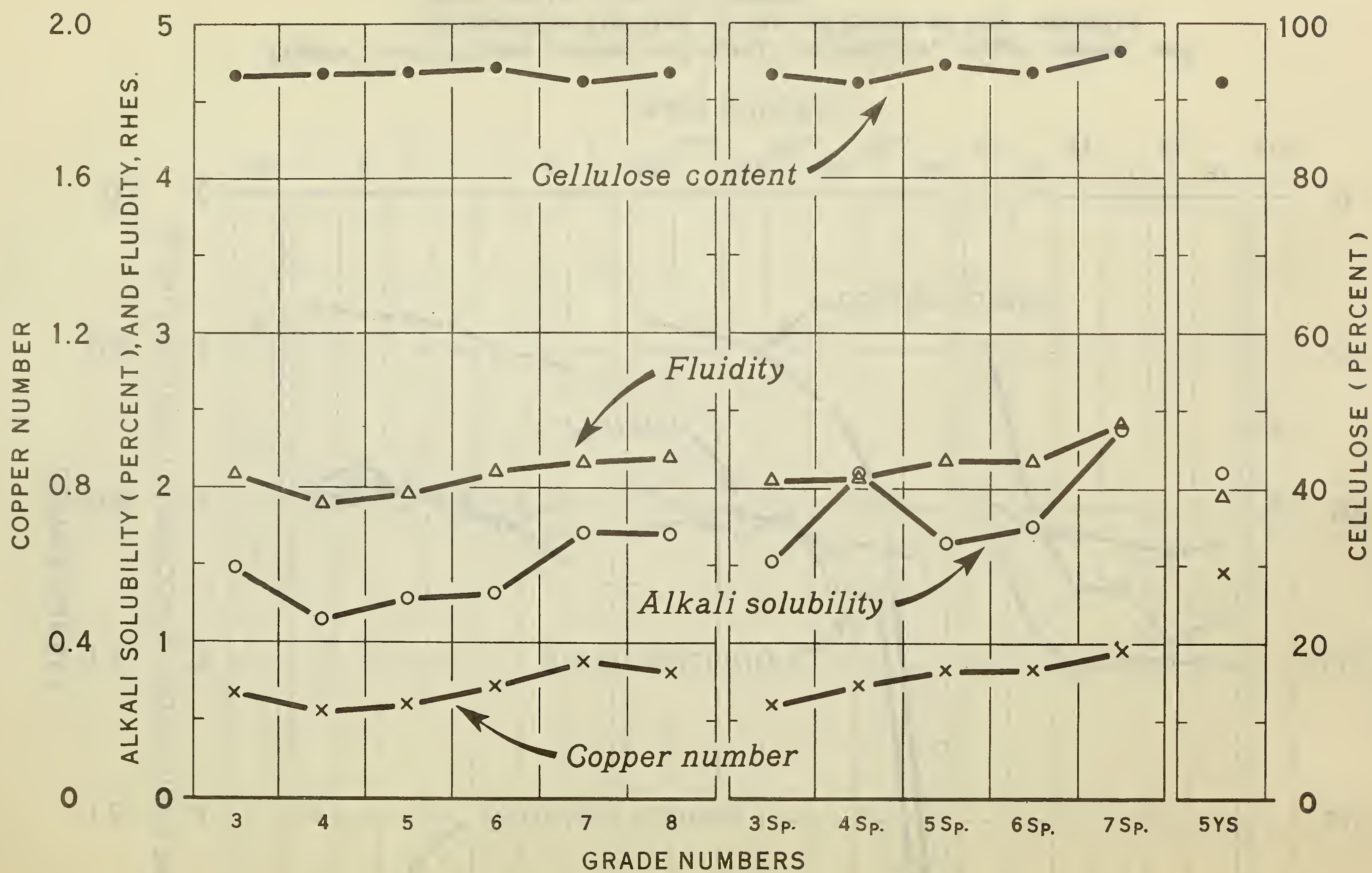

Figure 2.--Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Atlanta region

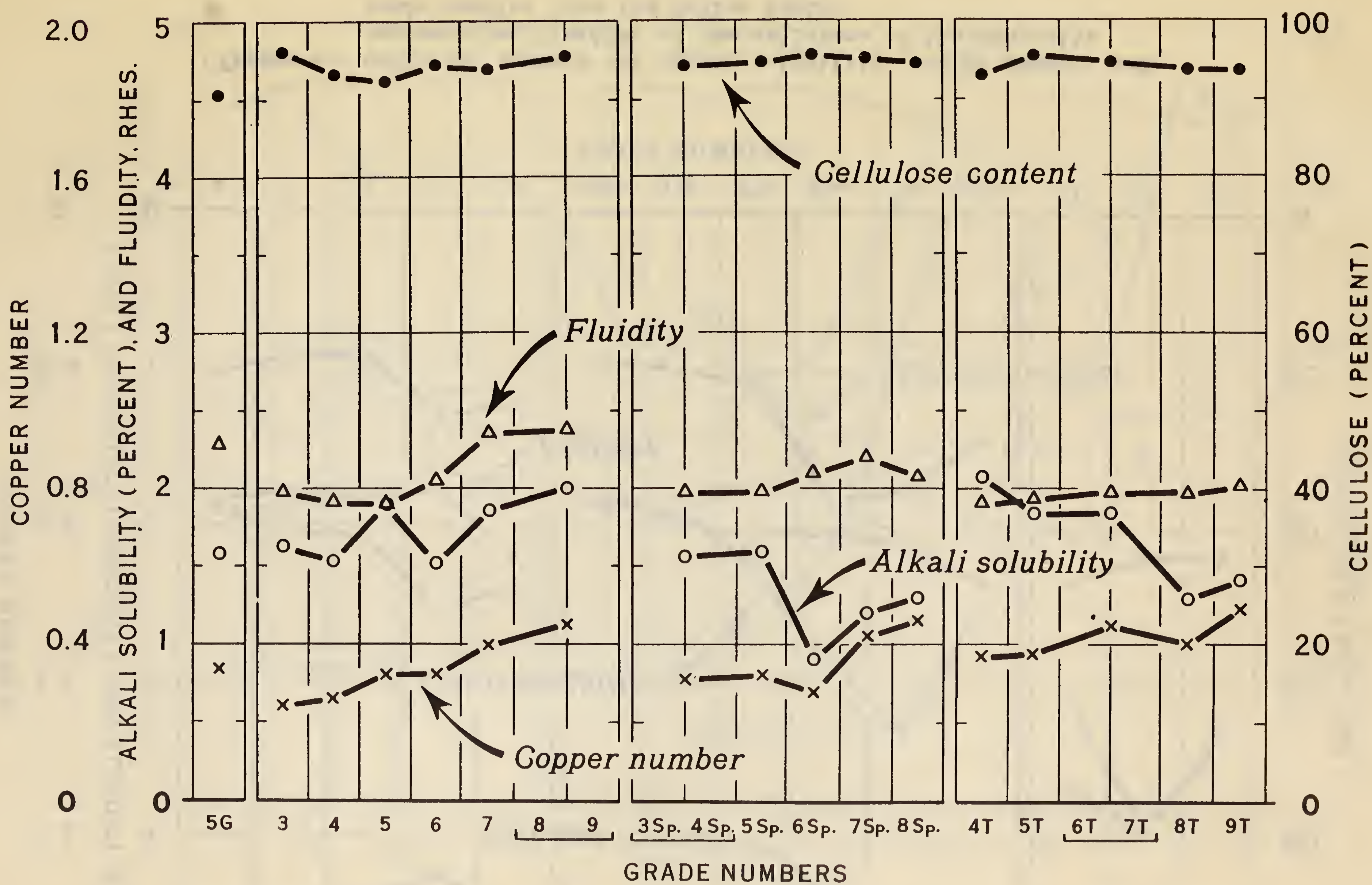

Figure 3.--Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Memphis region

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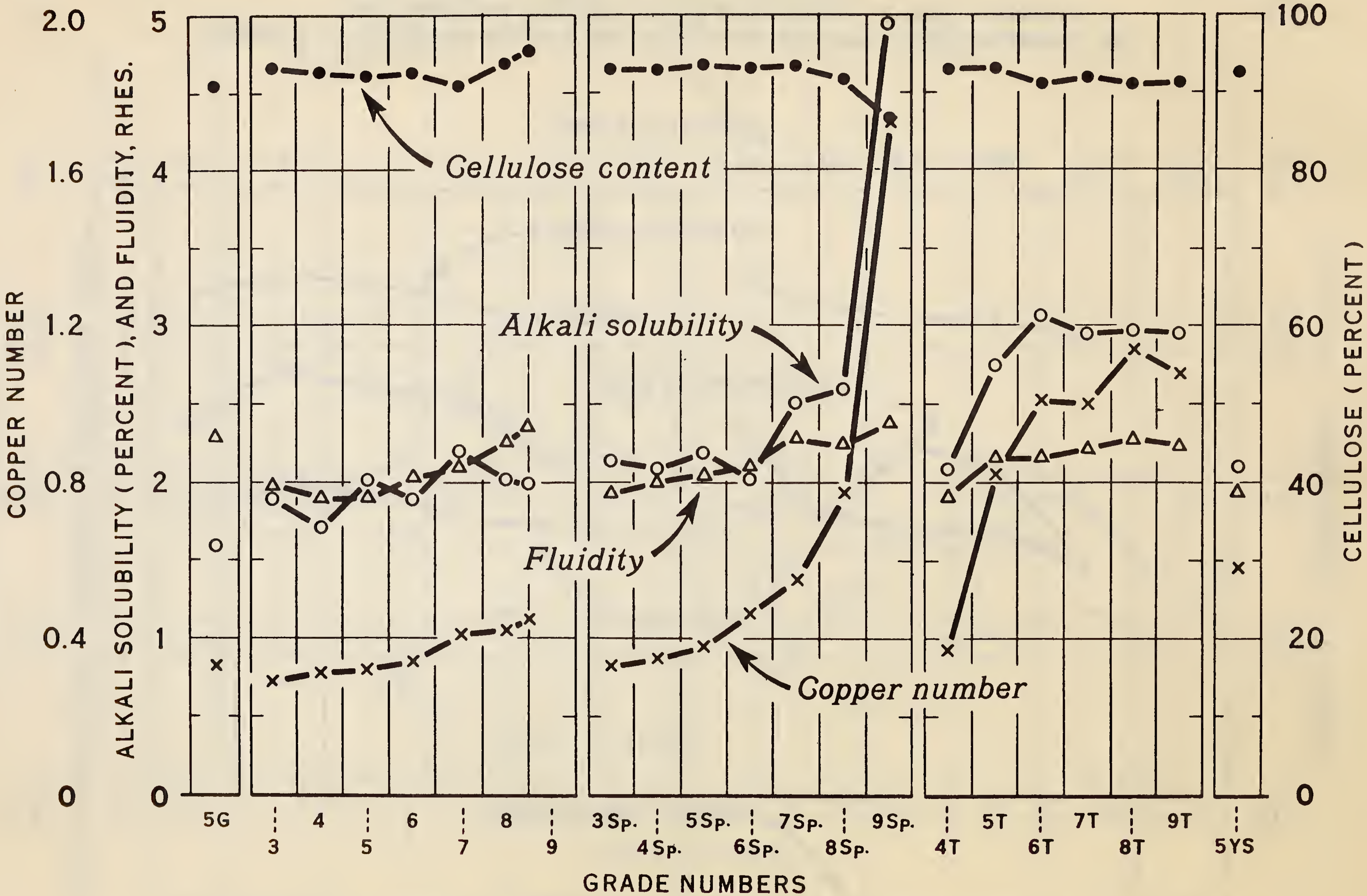

Figure 1.--Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from all regions

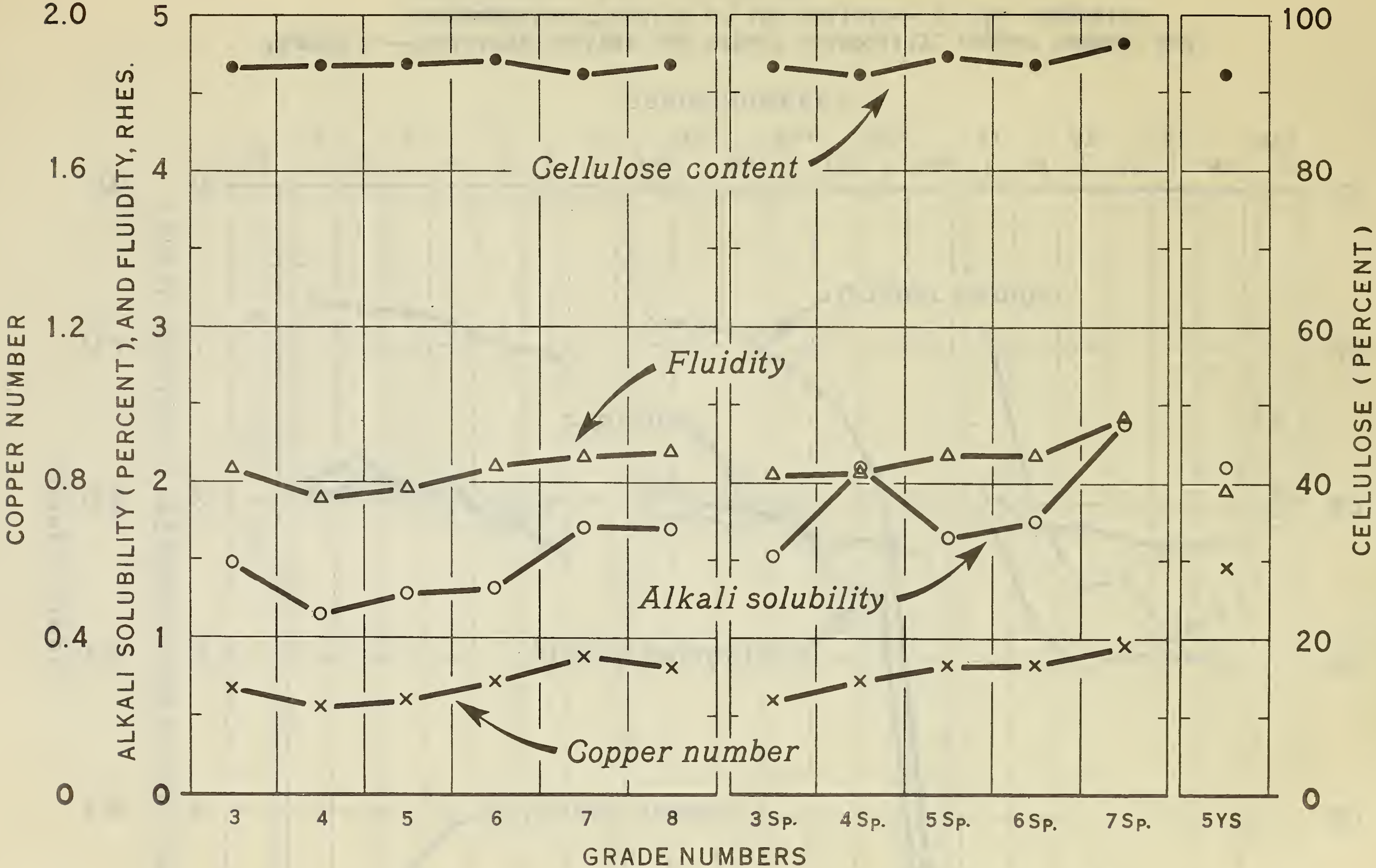

Figure 2.--Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Atlanta region

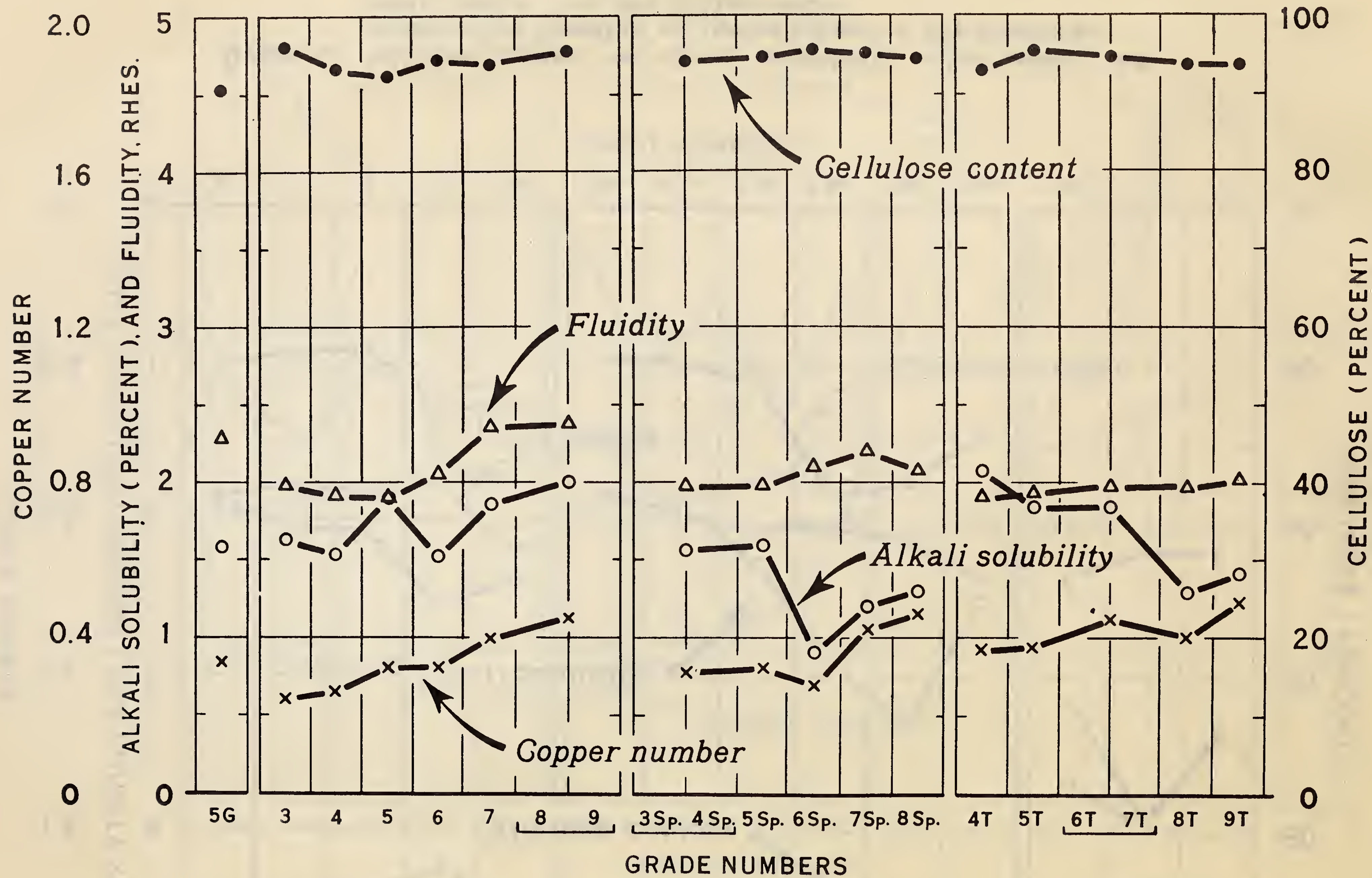

Figure 3.—Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Memphis region

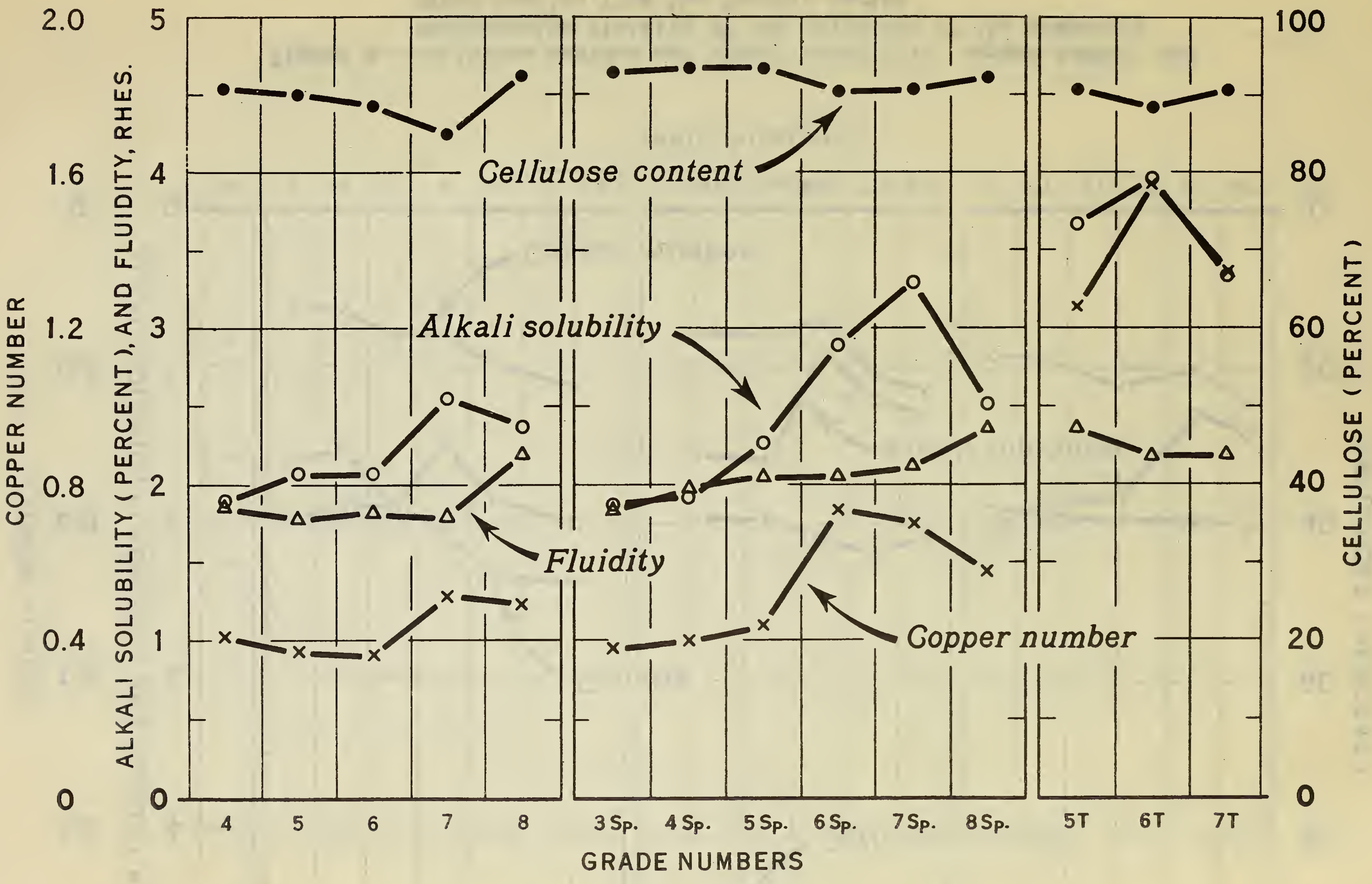

Figure 4.—Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Dallas region

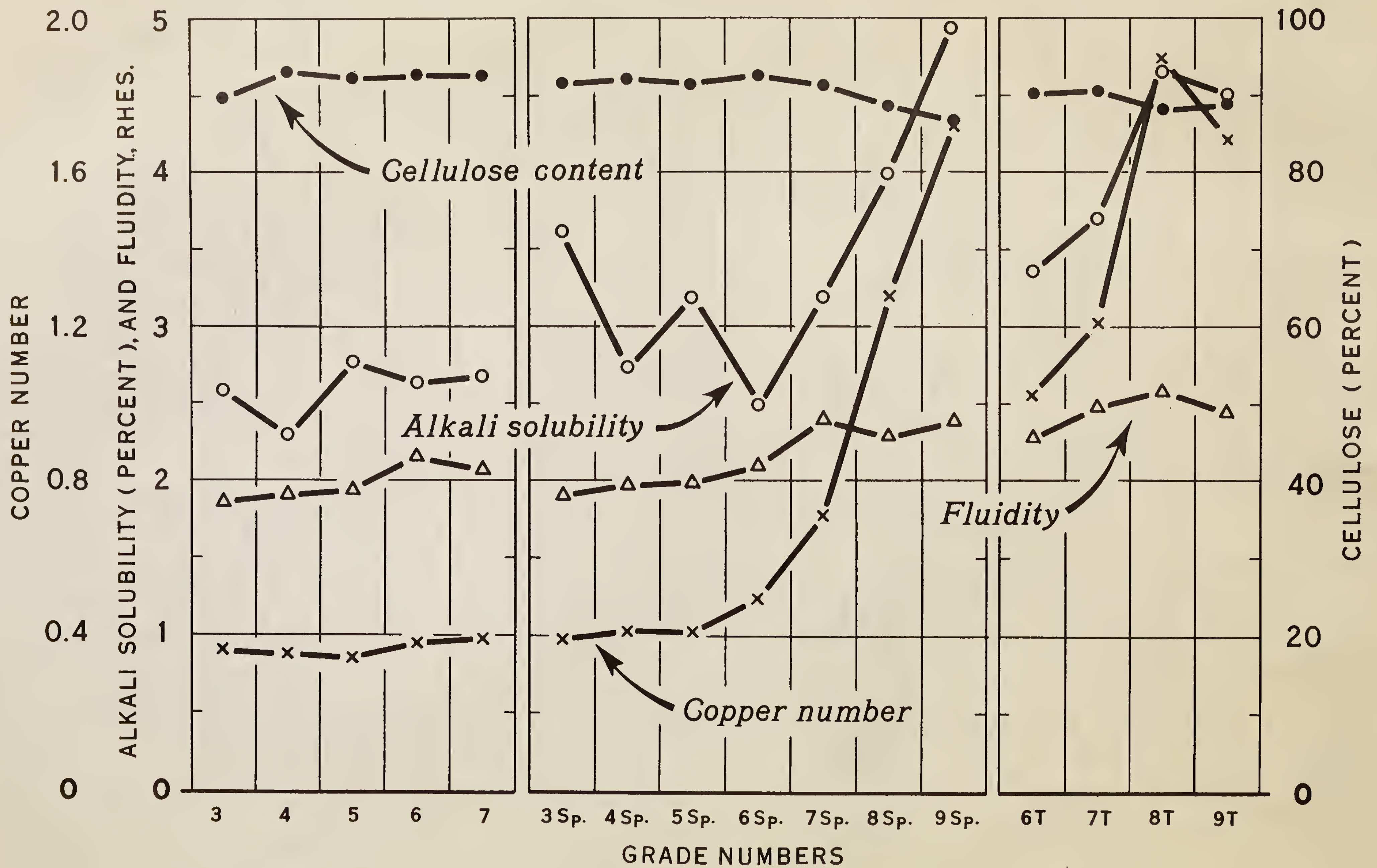

Figure 5.—Cellulose content and alkali solubility, copper number, and cuprammonium fluidity of the cellulose of the composite grade samples from the Austin region